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Comparison and Numerical Modeling of Seismic Structures and Single Pile Foundations in Wind Turbines

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ABSTRACT

The world today has an approach to clean and renewable energy and is moving towards the elimination of fossil fuels. Wind energy has created a competitive environment for other types of fuels, which reduces costs in renewable energy generation, shifts and prefers this energy to other types. Finally, the expansion of the industry is a technological breakthrough in achieving future goals in energy and the environment. The design of the turbines and the design of these turbines have been controversial issues in the industry and there have been various applications for use in these offshore structures, the most common of which are single piles and mono piles. Suitable,substrates for the construction of wind turbinesunder various environmental factors such aswind and waves; meanwhile many of these seas are in seismic areas affected by accidental earthquake loading. In this paper, nonlinear modeling of two single pile foundation and Payson Suction foundation models and its finite element analysis by Abacus software have attempted to study the bed and foundation response under environmental loads of wind, wave and earthquake, finally a step has taken to improve the design and optimization of wind turbines at sea.

KEYWORDS: *wind turbine, single-pile, seismic structures, soil seismic response*

I. Introduction

Not many years have passed since man has scientifically dealt with earthquake engineering. Over the years, the power of earthquake record keeping has increased, and more precise estimates have been obtained by performing mathematical analyzes on earthquakes and their effects on structures. During these years, earthquakes in different parts of the earth and its adverse life and financial consequences have forced engineers and officials to use science and technology, whether in the field of pre-earthquake affairs such as earthquake training, Geological and seismic studies, construction and reinforcement of earthquake resistant buildings; after earthquakes such as relief, crisis management, Reduce earthquake damage.The piling is one of the common methods used to tackle building vibration;piling rig has also used in areas where soil is not sufficiently resistant or loaded with large pavements or in wind turbines. However, the piling process also has adverse environmental effects.

Acoustic pollution and air pollution are the most common. The impact of these negative effects might be to some extent; however, the effects of the vibrations arising from the knocking of the candle can hardly be predetermined. It is also difficult to mitigate its adverse effects on vibration-sensitive installations, area residents, and on adjacent structures such as cracks, subsidence, inflation, and lateral displacement.Methods offered to mitigate the earth's vibration hazards due to pounding piles have often applied, such as limiting the use of pile-piles and shields, replacing piles with lighter piles, pre-drilling, or choose other solutions for the foundation. Today, with the rise of structures, including tall buildings, the load on structure to foundation increased, On the other hand, the increase in population and development of cities and villages calls for the expansion of construction even in areas where the soil has not well tolerated. Therefore, today more than ever it is necessary to pay attention to the issues of deep foundations and the advantages and disadvantages thereof. Piling is one of the most common and old methods of making deep foundations. Along with the benefits of using this method in seismic structures and wind turbines,the piling process also has negative effects, including adverse environmental effects such as noise pollution and air pollution. Moreover, more importantly, the adverse impact of the pile-hammer blows and the vibrations that they cause on adjacent structures and vibration-sensitive installations have consequences such as swelling, subsidence or lateral displacement of the soil around the pile due to condensation in the process of knocking the candle can's to be named (Hakman, Hagert, 1987). However, given the benefits of pile knocking in terms of ensuring proper implementation and higher reliability of soil loading and remediation, some solutions have needed to limit the side effects of the pile driving process. The pile characteristics are the dimensions, materials, and pile lengths of the soil geotechnical parameters, the point of departure from the bump site and depth of pile penetration in turbine. Other factors, such as the properties of the candleholder, the hammer and the candleholder, may also influence the vibration or vibration of the structure.

II. Research background

Mr. Yan Lee, Harrison in 1970, under the title Sequential Interaction and Constructive Interaction with Pile Impact carried out the first fundamental research into the interaction of structures and foundations with single piles. In this study, it has concluded that for ordinary load-bearing structures, the assumption of linear elastic behavior for the structure is a reasonable assumption; this research is in fact the basis of the static structural interaction theory.Further research into the issue of static interaction was carried out in 1972 by Messrs.' Yan Lee and Peter Brown. In this study, while emphasizing the importance of structural analysis of soil structure, it has compared to structural analysis with and without soil interaction effects. In this paper, after applying the interaction effect on the structure, it has observed that the effect of the interaction effect on the reaction of the structure have been reduced or decreased depending on the properties of the structure and soil, or as reinforcement and enhancement, without considering the effect. The action can reduce the reliability of the structure. In 2016, Fu and Di did research on the impact of foundation hardness on shear wall frames on structural behavior. They reported that the impact of foundation stiffness redistributes the stiffness of the structure so that the shear wall internal forces decrease and the internal shear forces increase. In addition, the shear and anchor forces of the columns increase significantly, which reduces the safety of the structure.

In year (2015), Hokm'abadi and Fatahi in an article examined the type of foundation in seismic performance of a structure by considering the interaction of the soil structure. They stated in their results that considering the type of foundation is a significant factor for considering soil and structural interaction and should have considered in the design for the safety and economic structure of this point.

In year (2014) and (2015), Zeidi et al. proposed a very accurate numerical approach based on Eulerian-Lagrangian view which is used mainly in this paper. It is noteworthy to assert the point that the mentioned result is also verified with 2 percent of error.

Shari et al. (2019), by using Numerical method and CFD technique could predict bottom intakes using turbulence transport equations which is implanted in this study with its robust validation.Mitra el al. 2019 asserted that controlling the structure of vibration data has attracted more attention over the last decades. Compressed Sensing (CS) is a novel signal sampling technique, which samples the signals under Nyquistrate has employed for sensing

structure sensors (Khoshnevis, Ghorshi, 2019). Amini et al. 2019 claimed that simultaneous sensing and compression via CS can be very effective in long-term monitoring of civil infrastructures by reducing the storage space and transfer bandwidth drastically.Ghadimi et al. (2019) by using intelligent wireless sensors and considering its impact on structural health monitoring could successfully predict that traditional algorithms require higher levels of memories which is utilized in this study.

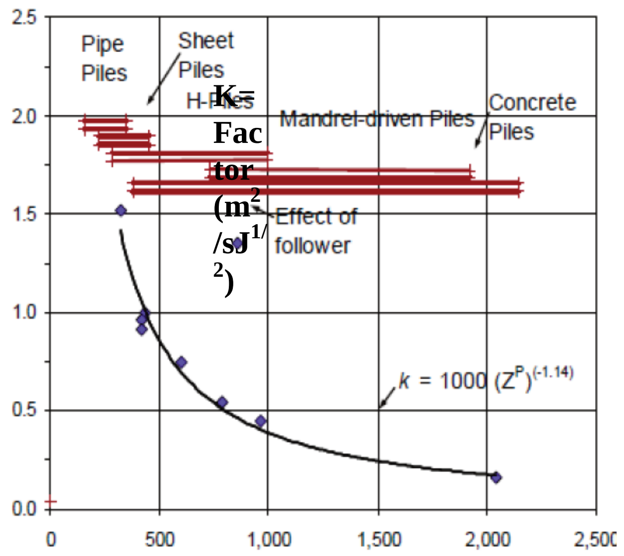
Research method:

The most common criterion for assessing the vibration rate of seismic structures along with single-foundation and the same-scale steel grounding parameters is the speed of particle peak. In 1981, it has concluded that the effects of distance and energy have applied together in a relationship such as the following equation. This equation, which has called the relationship of a scaling distance, has expressed in 1967 by Vis for the effects of explosion.

$$PPV = K\left(\frac{D}{\sqrt{E}}\right)^N$$

This has related to the high ***PPV*** particle peak velocity (mm / s), ***K***-factor dependent on the pile impedance, E_n hammer impact energy and ***D*** distance from the pile- bumping site. To obtain ***K*** it is necessary to obtain the value of the candle impedance.

$$I = \rho c A_p$$



Pile Impedance, Z^P (KNs/m)

Figure 1: Impact of pile impedance on energy transfer from pile to soil (Heckman \u0026 HAGERTY 1978)

Data analysis:

Its design and modeling assumptions have been that the Type 3 design area is one of the standard 2800 subdivisions. In addition, the area of the building is in the range with very high relative risk of earthquakes. The table below presents the soil characteristics of the area. The soil has considered soft clay.

Table 1: Soil profile Area

Soil Properties	
A	0.35
T0	0.15
TS	0.7
S	1.75

To investigate the seismic performance of the building at short and long heights and the investigation of various analyses, the construction frames have considered as the number of 4 and 11 floors.The height of all floors is meters and this structure has two spans in the X direction and four spans in the Y direction. The figure shows the plan of these models.The plan has chosen because of the use of a dual bending frame system with shear walls in conventional country buildings.As shown in this figure, the position of the columns is blue and the position of the shear wall, if any, is red.

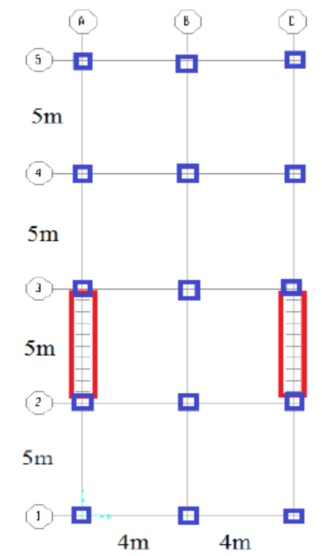


Figure 2- Model Architecture Plan

This is a case of pounding a pile in an ancient area in San Joaquin County, where Native Americans have lived for 1500 years.Eighty steel pipe piles, with a diameter of 180 KN to a depth of 20 meters, have crushed to the ground for the construction of four bridges.For knocking each pile, about 1800 to 2500 hammer blows.As illustrated in Fig. 3, field surveys have carried out at 4 points using the CPT test.The results of these experiments have shown

in Fig. 4 at 5 points and at different distances. Earth vibrations were measured using dimmer using three-dimensional geophones.Different values of PPV according to depth and distance at different points have presented in Table 2.

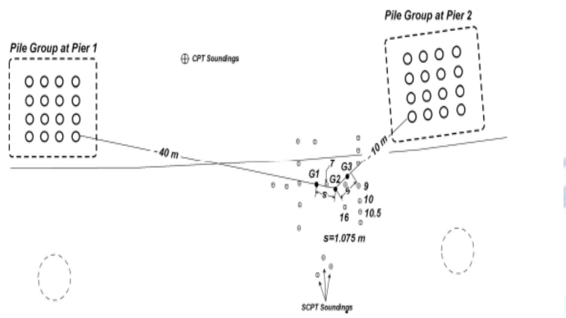


Figure 3: Site map and locations of the location measurements CPT (Brandenberg, 2009)

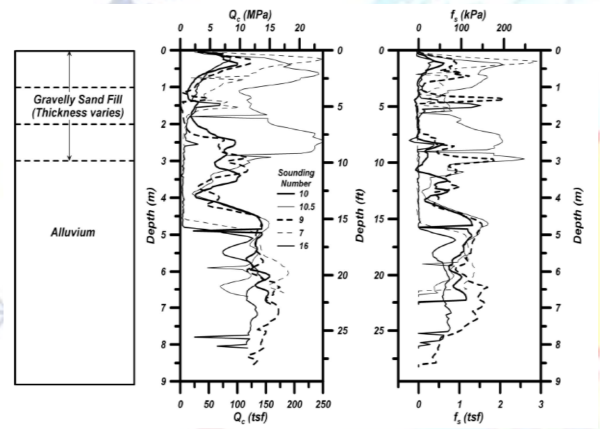


Figure 4: Results of the CPT tests in various speculations (BERACENBERG, 2009)

Table 2: PPV values for different distances and depth about high (BERANDENBERG, 2009)

Distance (m)	Depth (m)	PPV (mm/s)
40	0.0	5.15
40	1.2	8.7
40	3.7	5.12
40	4.6	5.6
10	0.0	13.7
10	4.6	17.2

Vibration measurements have made by five geophones at three distances of 10, 20 and 40 m from the pile driving.As shown in Figure 5, the three geophones measured the vertical vibration at 10, 20 and 40 m, and the 2 horizontal geophones at 20 m.The results of the vertical particle velocity measurements at different depths and for different distances have shown in Figure 4-2.

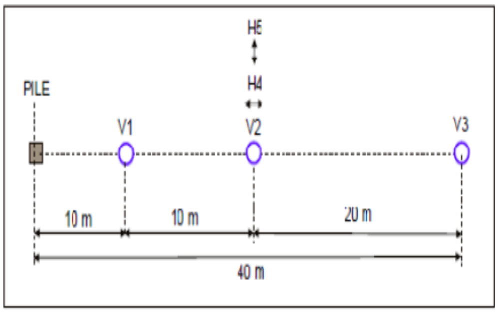


Figure 5: The position of pile and Geophone (FELLENIUS & MASSARSCH, 2008)

This practice case, described by JASKA and his colleagues in 2002, concerns the installation of an in-situ pile with a wide end.In this process, first, a pipe pile with a diameter of 500 mm in diameter has crushed to the ground and then filled with concrete.Characteristics of the pile-driving equipment include a hammer weighing 3.5 tons and a length of 10.8 meters with a fall height of 10 meters.The location of the pile driving is located in an area with the alluvial soil of the flood, which includes sedimentary deposits in a region of km 1 length.Local surveys of two main layers have diagnosed in 5.14 meters above the Earth, including:

The upper sedimentary soil layer consists of very poor sandy clay, silt and sand clay. Approximate thickness of this layer is 5.10 meters, which have changed in different parts of the site.

The lower sedimentary soil layer consists of sandy sand, which in some parts has sand layers with gravel.SPT experiments show the conditions of dense soil until very dense.In the following figure, the results of the measurements of Earth vibrations in the form of maximum particle velocity have shown according to the depth of pile penetration and the amount of distance from the site of the pile.

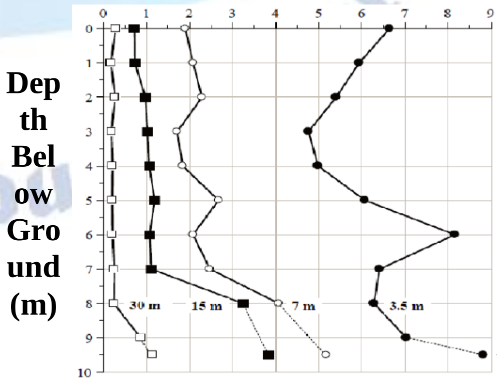


Figure 4: PPV relative to depth (JASKA, et al. 2002)

Usually the height of the fall in the hammer pile driving is about 1 meter.In this case, the height of

the crash is a 10-meter hammer stating that it is unconventional and very high.Therefore, due to the suspect of this case and the likelihood of the error, this has not used in computing.

III. Discussion and Conclusions

For linear analyses that have performed on structures, it can have to be stated that:

1- In the case of the main rotation of the period structure of the flexural frame structures, they are more than the flexural frame structures along with shear walls.Also, in all four modes of the first and second fashion and with walls and without walls, the amount of time of rotation for the mode that the structure comes with the Model Foundation has been greater. Moreover, this difference in the structures of the shear walls is about 10%, but in structures with the shear wall is about 60%.

2-About displacement of classes can haveexpressed in the following cases:

In general, the displacement of floors in the structure has less shear wall than the structure without a shear wall.In addition, the structures with the foundation have more displacement than structures in which the foundation dose not modeled.

3- To move the foundations of the building, you can also express the following:

The base displacement of structures that have modeled with the foundation is almost uniform in linear analysis and does not change suddenly.In the case of internal forces created in the column, generally in the bending frame system, and in the dual system with the shear wall, in the case where the foundation has modeled, it shows higher values than in the case of the non-modeled foundation.Due to the above, the lack of foundation modeling can reduce the reliability of the structure.

Results of Nonlinear Analyzes We now examine the results of nonlinear analyzes.In this analysis, the structures have also examined at various levels as outlined below.

1- Concerning lateral displacements of the classes, the following results can have expressed:

The amount of floor displacement in the nonlinear analysis in MRF structures is approximately the same for the different states of the structures with retaining bases as well as the structures with foundations at all boundaries.Also, the amount of floor displacement in nonlinear analyzes in MRF W structures for structures with clamped foundations is less than those modeled with foundation.In addition, in foundations with foundations, the lower boundaries of the foundations have more displacements than structures with high foundations of thickness.

2- The following results can have stated regarding the movement of the foundations of the building:

It can have concluded that the shear wall structures have non-uniform base displacements and part of the structures with high height and velocity have exposed to high leakage.In bending frame structures (MRFs), the structural displacements of the buildings are more balanced and uniform as the foundation structure moves upwards.In bending frame structures (MRF-w), the displacements of the building's foundations move upwards to the upper boundary. The displacements of the foundations of the building are more balanced and uniform.However, part of the surface below the foundation is elevated, which is in contrast to the flexural frame structure where the entire surface of the foundation is almost in subsidence.

3- The number and type of plastic joints formed in different members of the structure in the structures modeled with foundation and without foundation can have stated as follows:

Columns Joints:As it is clear that, the structures that have modeled with the foundation, especially about the 11-storey structure, the joints have gone from more areas that are functional.For example, in the 11-storey building along with a shear wall in the mode with the foundation, the column members have reached the range of LS and CP.

It can also have stated that in shear wall structures, the LS and CP joints are more likely to occur in the columns, especially in the 4 and 11 story structures.

Beam joints: The number and type of joints in a structure modeled with foundation and without foundation are not significantly different.However, it can have stated that the number of joints formed in the LS range and higher in shear wall structures is much lower than in structures without shear walls.

The joints in the walls also have no significant difference in the target displacement range.

In addition to the above, the upper and lower boundaries of the foundation can have examined.As it is clear from the tables, there is a tangible difference in the number of joints and their functional limit state is not present in beams and walls columns.The following diagrams can have expressed with respect to the cover diagrams, which actually represent the same base shear force.

Base shear values are much higher for shear wall structures than for wall less structures.There is also a noticeable difference between foundations modeled with foundations in shear wall structures rather than structures modeled with foundations.Concerning the diagrams of structures with high and low boundary thickness foundations that have related to bending frame (MRF) structures, it can have concluded that they do not make much difference.This is also the case for structures with high boundary thicknesses. Moreover, the structure with the thickness of the upper boundary foundation has baser shear.According to the diagrams of forces created at the junction of the surfaces and foundations in the moment frames and the 11 bending floors, the closer we get to the nix, the force generated includes the axial force, the anchor, and the shear.This result indicates that modeling regardless of the foundation, leads to a higher hand design that is not desirable.However, in frames with shear walls of 4 and 11 floors, the maximum force diagram in some buildings has fixed state and, in some cases, has related to one of the most expensive modeling of foundation.That is, in a few cases in the fixed state it is significantly less than the foundational expensive ones, which also demonstrates the importance of subsequent modeling in shear wall structures and the prevention of low-level structure design.

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